**Directors' Perspective: "Cheap-Ops"**

You can buy a Sony Walkman for $35. It cost more than $100 fifteen years ago when the dollar's worth was 50% greater. The cost of computers has come down drastically at the same time that computing power has increased exponentially. Long-distance telephone calls are much cheaper; so, too, are mobile phones. Many commodities have come down in price, with oil being the most remarkable. Gasoline costs less now in constant dollars than at any time since the 1940's. Across the wide spectrum of manufactured goods, services, and commodities, you pay less to get better quality today than you did only a decade ago. The business sector has enormously increased its productivity.

Telescopes are cheaper to build, too, and the new ones are much better than those we built even 15 years ago. They have faster focal ratios, so they are shorter and lighter. We understand the importance of thermal control to reduce dome seeing. Computers allow us to use alt-az drives, reducing the cost of mountings while simultaneously increasing their strength. Computer controlled mirror support systems let us use segmented (Keck) or thin-meniscus (VLT, Gemini) primary mirrors; in principle, these systems are scalable to apertures of enormous size: MAXAT (50m) and OWL (100m). We expect to build the NGST for a phase C/D cost of $500 million; a large part of the savings is that NGST will weigh 3700 kg, whereas HST weighs 11,000 kg, and cost tends to scale with weight for spacecraft. We have constructed more sophisticated instrumentation, and automated systems to point, track, and record data without requiring heroics from the observers.

The big telescopes have become *more* expensive to operate. Keck has an on-site staff of more than 60 people. A similar number of people work on instrumentation for the telescope. The VLT will need to maintain four telescopes and will require a larger staff. The Space Telescope Science Institute has a staff of 470 people, almost all of whom work full time to maintain the data flow from the Hubble Space Telescope. There are yet more people employed by Goddard Space Flight Center and in industry to service the telescope. Only 20% of the HST budget goes to STScI operations (~40 M$/year). Grants and fellowships are another ~28 M$/year. The rest, of order 160 M$/year is for new instrumentation, servicing, and flight operations. Gone are the days when a professor with a couple of ambitious graduate students and a technician could build state-of-the-art equipment to explore the heavens, at least not for the biggest telescopes.

There are gains, of course. The information content of a single observation is generally much higher than it used to be, in some cases by orders of magnitude, so the cost per bit of data has not risen as dramatically as operating expenses. Large CCD detectors deliver enormous amounts of high quality data – although we should temper our enthusiasm by noting that photographic plates in the 1920's provided more raw bits of information than today's CCDs. The principle gain is high quantum efficiency needed for the faintest objects, that are naturally the most interesting. Similarly, HST delivers images with such superb resolution that it has changed the nature of what we expect. Quite a bit of modern astronomy now *requires* this resolution and its correspondingly high price. HST set the bar higher both in quality and cost of data.

I think it is a good time to examine these costs and see if we can reduce them without sacrificing those services necessary to do great science. We provide many services at STScI, some of which we can almost certainly do more cost effectively than anyone else – calibrating the standard instrument modes, for example, and archiving the data. Others may be less expensive and just as effective if done by the users. Novel uses of the telescope or observations with rarely used configurations may be more successful if the expertise is vested in the community. Soon, there will be redundant capability on HST whose incremental support cost will be high but whose incremental scientific value is, at the very least, debatable.

Productivity gains in industry normally come at the cost of up-front capital investment for new equipment and training. When spread across millions of units, robotic welding equipment to manufacture automobiles or satellites to handle phone calls will greatly reduce costs in the long run even if they are more expensive to implement at first. We can achieve similar productivity gains by investing in software to handle routine tasks now being done by people, and we do it all the time. The STScI staff has decreased by 14% since 1993, when it peaked. Our data rate has more than doubled, and a smaller staff provides more services for more complex instruments than in the past. We are implementing new software to automate the grant awards, handle our accounting systems, and translate scheduling information for the telescope from people-oriented language to machine code. All of these investments cost money, principally by using STScI software engineers to write and debug new code. It makes sense for some areas but would be wasteful for others, where the number of "units" – observation blocks, special instrument modes, or user inquiries – is small. Our support of NGST will make possible more of these productivity gains by spreading the infrastructure costs over two projects.

NASA sets our budget assuming no change in the level of support for science instruments and no change in the number of services we provide. The agency wants to do everything it can to insure the continued great flow of data from HST. But we will do ourselves a service by becoming more efficient before we face budget cutbacks – they are inevitable. And we are looking forward to the era of the NGST with the important assumption that we can operate it for about 30% of the cost of operating Hubble. We are working now to meet this goal; it will depend on some discipline in mission design, but it should be doable. In the meantime, it is useful to ask if we can reduce the costs of running HST. If we can make gains in our HST productivity, it bodes well for the future of space astronomy.

This effort will start at STScI and involve the users through community dialogue. The user's committee, STUC, should play a major role in helping make the tradeoffs between essential and non-essential services. Some of the changes will be transparent to the user, resulting from internal improvements in the way we carry out tasks. Some will involve changes in the way the users work and what they expect from STScI. I do not see much waste in our current system. We scientists should demonstrate that we can increase productivity just as industry does. It may get the attention of our supporters if we who use astronomical facilities for research can do increase our overall output without more input. Food for thought.

Steven Beckwith
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